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DISTRIBUTED INFORMATION SPACE AS AN ASSOCIATIVE ENVIRONMENT OF COMMUNICATION SETTING

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Abstract. *Modeling the structure of a distributed network can be based on the architecture of an associative infocommunication network, which displays the processes and mechanisms of interaction of components in the corresponding nodes of the structure. It is shown that for the description and functional representation of a distributed network, it is appropriate to apply decomposition for the field of software engineering, the purpose of which is to create theories that interact with each other according to well-defined rules. A conceptual representation of the distributed space behavior model is given. The paper discusses the modeling of the evolutionary search.*
Keywords*: infocommunication network structures, distributed information space, associative interaction of system elements and components, modeling of distributed information space.*

Аннотация. *Тақсимланган тармоқ структурасини моделлаштириш тузилманинг мос тугунларида компонентларнинг ўзароалоқаси механизмини ва жараёнини акслантирадиган ассоциатив инфокоммуникацион тармоқ архитектурасига асосланиши мумкин. Тақсимланган тизимни тавсифлаш ва функционаллигини намойиш этиш учун дастурий таъминот инженерияси соҳаси учун декомпозицияни қўллашни ўринли эканлиги, буни қўллашдан мақсад, аниқ белгиланган қоидалар асосида бир-бири билан ишлаш ўзароалоқа назариясини яратишдан иборатлиги кўрсатилган. Тақсимланган макон ҳаракатининг моделига концептуал моҳият берилган. Тадрижий қидиришни моделлаштириш кўриб чиқилган.*
Таянч сўзлар*: инфокоммуникацион тармоқ структураси, тақсимланган ахборот макони, тизимнинг элементлари ва компонентларини ассоциатив ўзароалоқаси, тақсимланган ахборот маконини моделлаштириш.*

Аннотация. *Моделирование структур распределенной сети может быть основано на архитектуре ассоциативной инфокоммуникационной сети, которая отображает процессы и механизмы взаимодействия компонентов в соответствующих узлах структуры. Показано, что для описания и функционального представления распределенной сети уместно применять декомпозицию для области инженерии программного обеспечения, целью которой является создание теорий взаимодействующих друг с другом по хорошо определенным правилам. Дано концептуальное представление модели поведения распределенного пространства. Рассмотрено моделирование эволюционного поиска.*
Ключевые слова: *инфокоммуникационные сетевые структуры, распределенное информационное пространство, ассоциативное взаимодействие элементов и компонентов системы, моделирование распределенного информационного пространства.*

Introduction

Distributed infocommunication network, which is a complex system of functionally connected set of hardware and software for processing and exchanging information, consists of geographically distributed information nodes where information is processed, and physical communication channels [1].

To study the characteristics of the functioning process of such a complex system (which can be attributed to the class of large systems, given the variety and complexity of its components), an infocommunication network is decomposed, allowing it to be considered as a set of structures, each of which contains elements that are highlighted at the corresponding level of network consideration: the totality of physical channels determine the physical structure; logical and informational structures describe the placement and relationships in the information and communication network of various information processes that determine its construction and functioning.

Along with this, the system modeling methodology [2], which serves as the conceptual basis for a system-oriented structuring of the subject area, provides for the construction of a model of the system and the corresponding subject area, which describes the most important aspects of the system from the point of view of the problem being solved.

The principles of system analysis and system modeling are applied to models that are associated with information or logical modeling of systems.

As you know, mathematical modeling is the process of establishing compliance with a given real object of a mathematical object - a mathematical model, and the study of this model to obtain the characteristics of the real object under consideration.

The most important characteristics of any system are its structure and the functioning process. Under the structure of the system is understood to be stable over time, the set of relationships between its elements or components; the structure of the system can reflect a variety of relationships, including the nesting of the elements of one system in another.

The process of functioning of the system is closely related to the change in the properties of the system or its individual elements over time; Moreover, an important characteristic of the system is its state, which is understood as a set of properties or signs of the system, which at each moment of time reflect the most significant features of the system's behavior.

The process of system modeling can be represented in the form of interconnected stages, at each of which certain actions are performed aimed at the construction and subsequent use of information-logical models of systems. Another of the principles of system modeling is that to build an adequate model of a complex system, you may need not one, but several models of the system. In this case, each of these models will be a separate representation of a complex system, and the complete system model will consist of a set of interconnected models.

A conceptual model of a distributed environment. Principles of modeling component behavior

The complex information processes taking place in the infocommunication network structures determine the need for research and development of mathematical models of various types and levels of detail. Based on this, the modeling task will be associated with the construction of such a model of a distributed infocommunication network, where its components - individual functional models - will be determined by the functional purpose of the individual elements, as well as the effective organization of relations between them.

As functional models, it is advisable to consider: a logical structure model that defines interaction technologies based on information exchange protocols; A model of the information structure that describes information processes in a distributed network in terms of access to resources and applications. Determining the characteristics of the network depending on the parameters of individual functional models and organizing the relationships between them will allow us to analyze the behavior of the network under various conditions and to develop effective mechanisms and procedures for the exchange of resources and processes.

The logical structure model will be based on the definition of a distributed system adopted for distributed systems, according to which, from the point of view of one of the computers (nodes), all the other machines (nodes) included in it are remote computing systems.

The theoretical basis of the network interaction of remote systems is the model of interaction of open systems, which divides the process of interaction of two parties into levels; at the same time, in distributed networks, to fulfill the requirements for data exchange, the functions of the session and representative level are assumed by the intermediate environment (middleware, middleware), which allows creating open, scalable and stable distributed systems.

To achieve this goal, the intermediate environment should provide services for the interaction of components of a distributed system, such as providing a single and independent of the operating system mechanism for using one of the software components services of other components, ensuring the security of a distributed system, ensuring data integrity, balancing the load on servers with software components , detection of remote components [3].

In other words, in the logical structure model, it is necessary to take into account the features of the implementation of an intermediate environment or other mechanism that allows you to configure the components of a distributed network.

The information structure model, in turn, must take into account all processes in a complex network distributed in space, which can be described not only as a hierarchical multi-level, but also multi-dimensional representation [4], combining, integrating and combining dispersed network and system resources for solving certain problems. The development of an information model in the context of the problems solved in the dissertation is proposed to be carried out on the basis of the principles of organization and functioning of the associative infocommunication network environment, which allows representing hierarchy levels of the information field and assuming hierarchical interconnections of these levels.

In other words, the basis of modeling is an information structure that displays the processes and mechanisms of interaction of information flows at the corresponding vertices or nodes of the structure: the correspondence of information elements is determined by quantitative and qualitative parameters when transmitting information, making an access request, searching for information, etc. Determining the correspondence of associative features to a specific information element of the associative structure is a separate task that requires studying the properties of information exchange mechanisms, taking into account the multi-level (multi-dimensional) representation of a distributed infocommunication network.

A complex system distributed in space, consisting of a set of autonomous machines (nodes) connected by communication networks and equipped with software (software) or software systems, aims to create an integrated and integrated information and computing environment. This goal is associated with the provision of such requirements for distributed systems as separate use of resources, openness, parallelism, scalability, fault tolerance, and transparency [5].

In other words, a functionally connected set of hardware and software for processing and exchanging information that reflects a particular requirement is geographically distributed in a variety of information nodes (information processing subsystems), whether it be personal computers or powerful server machines, local or global networks, and also such systems, like distributed operating systems and / or application software.

For the description and functional representation of a distributed network in the form of an intermediate environment, it is appropriate to apply decomposition, including in the field of software engineering [6]. For this, a multidimensional decomposition is used, which allows modeling processes based on organizational, architectural and aspect principles.

As noted earlier, distributed infrastructure is represented by a set of interconnected nodes exchanging messages over the network; each node operates according to its own exchange algorithms, imposing certain restrictions (including the delay time) on the general process of information exchange. Regardless of what type of exchange it is - for a single object (one service), when the servers are involved in the exchange - direct and / or potential participants of the exchange and clients initiating requests for objects from servers, or for many objects (services), when servers can to act as clients for some objects themselves - its implementation requires appropriate coordination between various services whose functional purpose is to fulfill certain client requests.

In addition, the processing of a complex request, when hierarchically ordered sets of connections can participate in the exchange process, with the splitting of the complex process into simpler ones, implies the existence of special links that will serve as a kind of “service labels”, allowing you to take into account the dynamic nature and spatial distribution of application components and system resources; and integrate structured and unstructured resources. For a system model of a software component, it seems appropriate to formalize the processes of information exchange in a distributed network environment, which will enable the study and development of specific solutions for distributed systems and networks of varying complexity.

Thus, the processes of information exchange in complex distributed structures require appropriate control mechanisms based on a proper description that takes into account the different sequences of the formation of message components.

A distributed information space of states is a set of objects related to or related to processes. In this case, methodologically, the decomposition with respect to the components and the representation of the state space for various components and information is performed in such a way that connections at one or another level can be defined in the model (Fig. 1).

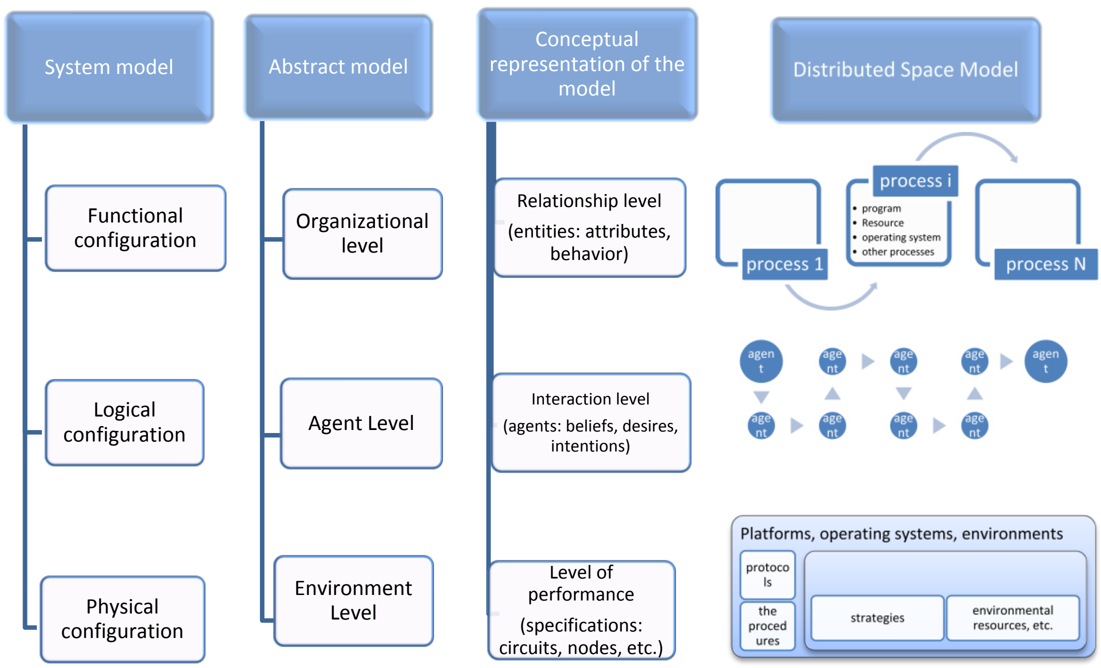

Fig. 1. ***Conceptual representation of a distributed space behavioral model.***

Such a representation allows one to determine and detail the set of internal structures of a distributed medium, its component components, their connections and possible interactions between components, including the properties of these components, by defining the corresponding structural elements that are selected through the interaction interface at various levels of abstraction (for example, through the structure of software classes, possible scenarios for the interaction of components, etc.).

Along with this, in a distributed space, an application is implemented through a set of autonomous processes, appears to be a multi-agent system, and is supported by the underlying environment, i.e. a proper degree of functionality can be provided at the required level of consideration, which makes it possible to switch to a programming model through a behavioral model of a distributed environment (space), and, accordingly, to a software architecture or a modification of its development process, including the mapping of computational tasks to the architecture of computing tools.

In a distributed space, depending on the task, a set of objects is formed, the behavior of objects, their properties, the establishment of relations between objects are determined, the interfaces for each object and the implementation of the object are specified. Important in this case is the justification that in OOP the computational process is understood as a system assembled from modules that interact with each other and have their own methods of processing incoming messages. To describe such a process, an agent-oriented approach is used, which in computer science and artificial intelligence develops well-known approaches based on the concepts of objects and actors, and at the same time has a number of fundamental differences [7]: the concepts of object and actor are essentially the original units software systems defined by some structure and interaction mechanism. An agent is a more complex, active and autonomous unit, and therefore, an agent-based approach refines this framework by recording the activity of modules - agents and changing their states using concepts of beliefs, desires, decisions, etc.

On the other hand, the introduction of agents to describe the behavior of distributed entities allows us to ensure the proper level of their focus. This shows that the agent, being an “active object” or “artificial figure”, shaping its own behavior (or at least participating in this process), is at a significantly higher level of complexity with respect to traditional objects in the PLO [8]. The position of agents can interpret the proper “level of subjectivity” in an artificial system, and the distributed space itself can use the principles of the formation of intelligent systems (which, by definition [9], is understood as a combination of hardware and software integrated by the information process, capable of information and knowledge if available motivation to synthesize the goal, make a decision to action and find rational ways to achieve the goal).

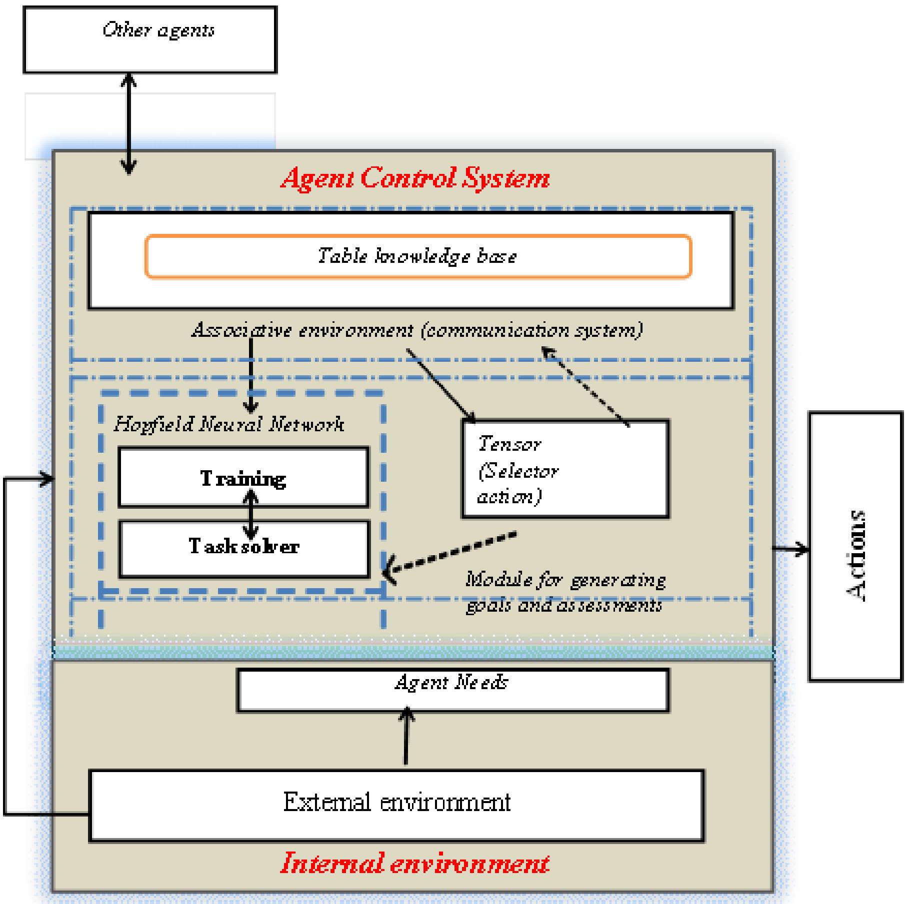

Fig. 2. ***Agent management diagram in a conceptual representation of a behavioral model.***

Given that the behavior of an agent in a multi-agent system is determined by its management system, it is advisable to consider the agent management scheme, the development of which is an important part of solving the problem. The agent management scheme in the conceptual representation of the distributed space behavioral model is shown in Fig. 2.

Consider the principles of modeling and implementation of the corresponding blocks of the above scheme.

It is important to note that the optimization of agent behavior takes into account the following factors during modeling:

1. Evolutionary search: a module of communication with other agents (highlighted in the diagram by a dash-dotted line) - a model of an associative environment.

2. Individual training and choice of action: the module for generating goals and assessments - a model of the Hopfield neural network and tensor transformation.

3. Exchange of experience between agents as a result of communications: effective interaction of components in a distributed environment - a model of a multi-agent system based on fuzzy sets.

The implementation of the principles of modeling for each of them will be determined by the corresponding model, taking into account the above multidimensional decomposition.

Modeling evolutionary search. Associative environment as a communication system

In accordance with the provisions of intelligent systems, the implementation of information processing and control technologies, and, consequently, the organization of the computing process, largely depend on the implemented principle of system organization in each case, on the basis in which models of dynamic objects and processes are presented, as well as from a number of other factors. Moreover, the changes that occur as a result of informational interactions between the sets of elements of the same hierarchy level can be both quantitative and qualitative. The former are characterized by changes within information systems, the latter by changes in the hierarchical structure, as well as changes in relationships and relationships between sets of information systems at different levels of the hierarchy.

For a quantitative analysis of information processes, determining the effective configuration of the interaction of network components and a detailed assessment of the functioning of information systems in the network, a systematic approach is proposed that allows the description of information processes based on associative connections.

According to the definition [10], an association or associative connection is the establishment of similarity / differences between the representations of two or more objects or events, while the defining characteristic of the space of a multi-coordinate associative environment is the implementation in it of a chosen similarity measure, interpreted as the distance between the analyzed information objects, presented in the form of ordered sets of elements of some sets, based on the introduced space metric. Having accepted this definition as acceptable not only for memory structures, we will conceptually expand it for the information space of an infocommunication network [11]: a hierarchical multi-level representation of a network with many information connections between architectural and system components can be defined as an information space corresponding to the space of an associative infocommunication network transmission medium and processing information consisting of a hierarchically ordered set of metric spaces is defined dimension.

Moreover, hierarchical relationships between the metric spaces of the environment are organized in such a way that each metric space displays one or more information objects that have the following associative properties and allow the implementation of procedures (such as access to an information element, changing structural relations between elements, etc. .) their representations and transformations:

- ensuring compliance of information structures with the structures of their presentation in the environment;
- multidimensionality of the network environment space;

- multi-coordinate access to associative cells in all areas implemented in the environment;
- implementation of associative interactions between information objects;
- multiport access to information structure elements;
- masking of associative cells to perform various operations on information structures;
- reconfiguration of the elements of the associative environment when performing various interactions;
- tuning and training of individual associative cells and the environment as a whole to perform various procedures for the presentation and transformation of information.

Obviously, manifestations of other properties of information objects in the network are also possible; the study of such properties is a rather difficult task, requiring the development of an appropriate model, determining the methodology for analyzing information processes. For these purposes, based on the concepts of associative environments, you can determine:

- information field Q as a set of information about the state space of the information system;
- the hierarchy level of the information field Q_L (where L is the hierarchy level) - information from the information field Q, which can be reflected by information systems of a certain level of organization of the level model in all sets of cells of the corresponding L - th (not higher) hierarchy level $U(\{P_{K(L)} / K = 1 ... Z ... X\})$;
- layer of the hierarchy level of the information field $Q_{J(L)}$ (where L is the hierarchy level, J is the index of the layer) – information available to a separate subset of information systems of a certain hierarchy level (reflected in a separate population (in the extreme case, in a separate set $P_{K(L)}$) sets of elements of the L th hierarchical level $U(\{P_{K(L)} / K = 1 ... Z\}), U(P_{K(L)})$)).

The above provisions are applicable for modeling information processes: when modeling a network graph $G(V, R(V))$ you can represent a variety of all kinds of pairs of nodes D_0: $D_0 = \{(s, d) \mid s, d \in V, s \neq d\}$, where the first element of the pair will correspond to the source node that initiates a certain flow of information, and the second to the destination node. Thus, any task related to information transformation can be described as a set of tasks of interaction of virtual elements $H_{K(L)}$, $D_{K(L)}$ and $U_{K(L)}$ of the corresponding network nodes.

If V_I – network nodes, represented by a set of virtual objects, characterizing the information interactions of different levels of information systems $V_I, (V_I \subset H_{K(L)}, D_{k(L)}, U_{K(L)})$:

$$\min\left(\sum_{c \in Pc} \sum_{\substack{i,j=1 \\ i \neq j}}^{N} U_{ij}^{c} C_{ij}^{c} + \sum_{s \in Ps} \sum_{\substack{i,j=1 \\ i \neq j}}^{N} H_{ij}^{s} C_{ij}^{s} + \sum_{d \in D} \sum_{\substack{i,j=1 \\ i \neq j}}^{N} D_{ij}^{d} C_{ij}^{d}\right) \tag{1}$$

where: N – a set of elements of one level; Pc – source node processes; Ps – processes of the receiving node; $Cxij$ – conditional cost of communication when requesting an information object on element j from element i.

Obviously, the value of $Cxij$ will be determined by the efficiency of the processes for managing heterogeneous components (objects) in a distributed environment formed by infocommunication network structures. The conditions for the execution of this expression may be restrictions on access of any resource, features of the application implementation, etc. [12].

It is important to note that in this representation, two concepts are used to describe the task of the information interaction of objects in a distributed environment: data (as a result of information exchange) and computing (as a process), which are different for different applications. The effectiveness of a distributed environment is determined and depends on the results of process control associated with the provision of data and the implementation of calculations. The data is described by attributes of entities in the environment, and the calculations relate to the behavior of entities.

Distributed architecture, as a combination of physical, logical and structural elements of a network, the relationships between them and the rules for their interaction, involves hierarchical multi-level relationships that can be displayed in the form of models, each of which highlights the essential elements of its level of abstraction; at the same time, information exchange mechanisms will possess a number of properties due to the nature of exchange in physical, logical, and structural configurations, respectively.

A distributed system consists of a set of processes (located in distributed network nodes), the interaction of which is carried out by a communication network that provides a means of information exchange between processes [13]; application processes that provide input, storage, processing and issuance of various types of information are performed in systems and interact through a telecommunication network, and this interaction is carried out for a particular service or application (Fig. 3).

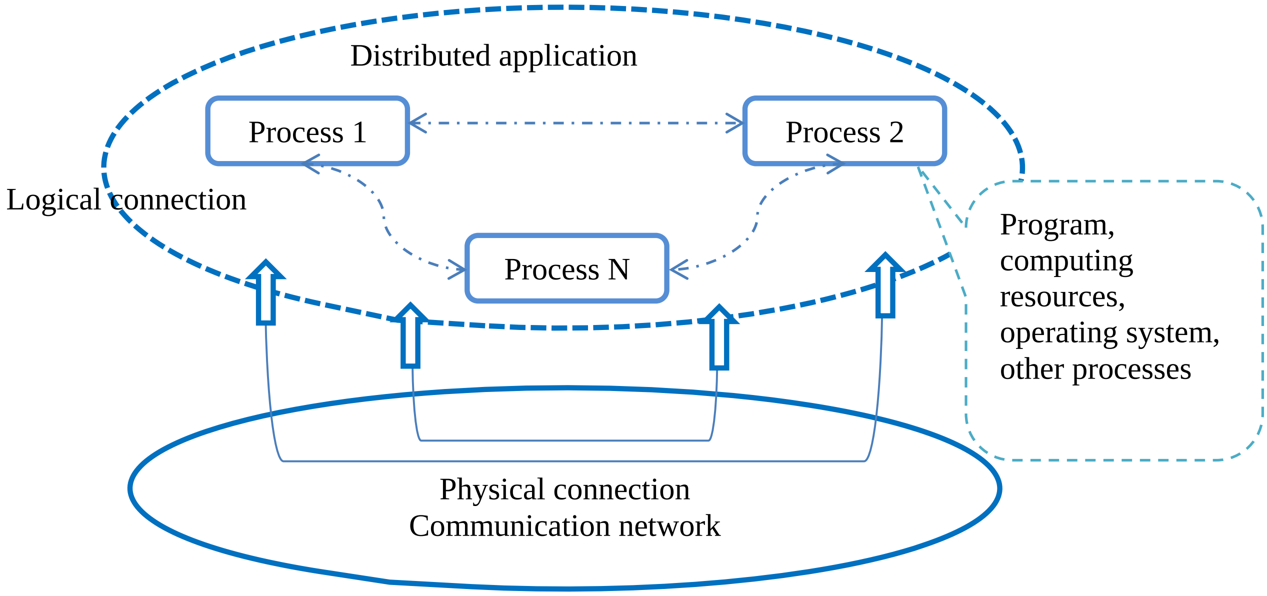

Fig. 3. ***Distributed application as a set of processes.***

A distributed application is considered to consist of many processes (programs, computing resources, operating systems, other processes) that perform a task, while a communication network transmits messages between processes in a coordinated manner for exchanging data and information).

The functionality of a distributed environment, and accordingly its functional architecture, are completely determined by the needs of applied processes in the transfer of various types of information. At the same time, the basis for constructing the functional architecture of modern distributed systems is the protocol profile, which is an interrelated list of protocols (standards) and ensuring the implementation of the relationship functions.

Thus, a system model can be described by a graph whose vertices represent processes, and the edges represent directional communication channels. A distributed application consists of a set of processes $p_1, p_2, .., p_i, .., p_n$, that interact through network messaging. The processes p_i and p_j exchange the message m_{ij} over the communication channel. Process execution and message passing follow the widespread model of asynchronous exchange [14], which is widely used in a distributed computing environment. In general, a set of states of processes and communication channels is a state of distributed computing. The execution of a separate process is the sequential execution of individual actions described in the model in the form of three events: internal events, message sending events, message receiving events. This is consistent with the classical model of distributed processing described in [15].

For the process p_i we accept the event x as e_i^x; for message m, the send and receive events will accept *send(m)* and *rec(m)*, respectively. In the event that events occur, this leads to changes in the corresponding processes and channels, and a change in the state of the system: an internal event changes the state of the process to which it relates; a send/receive event changes the state of a process that sends / receives a message and the state of the channel involved in this process. The events for any process are linearly ordered as they occur: the execution of the process p_i - is a sequence of events e_i^1 ,e_i^2 ,...e_i^x , e_i^{x+1},..., denoted as S'_i, i.e.

$$S'_i = (s_i, \rightarrow_i),$$

where s_i– is the set of events initiated by the process p_i , and the ratio $\rightarrow_i$ determines the linear sequence of these events.

Information exchange between processes is carried out through events of sending and/or receiving messages, i.e. for each message m exchanged between two processes, you can write: $send(m) \rightarrow_{msg} rec(m)$.

Running a distributed application is a collection of distributed events (processes), i.e. $S = \cup s_i$. The → relationship between events in distributed computing determines the order of events $S'=(S, \rightarrow)$, that occur depending on the distributed algorithm [16], as well as the causal relationship of the processes involved in distributed computing (event occurrence).

In general, you can write:

$$\forall e_i^x, \forall e_j^y \in S, \quad e_i^x \rightarrow e_j^y \quad \Leftrightarrow \quad \begin{cases} e_i^x \rightarrow_i e_j^y \\ e_i^x \rightarrow_{msg} e_j^y \\ \exists e_k^z \in S : e_i^x \rightarrow e_k^z \wedge e_k^z \rightarrow e_j^y \end{cases}, \tag{2}$$

Using such relationships, various procedures can be recorded during the operation of a distributed object in terms of information interaction. For the purposes of modeling distributed space, a so-called internal model of an agent is being developed as a representative of an object (or group of objects) in terms of object-oriented programming. It is advisable to distinguish between the steps shown in table 1.

Table 1.

Stage	Description Stage	Presentation
1. Objects and their properties are determined	Depending on the task, objects and their properties are identified	Software Engineering Principles
2. The behavior of objects is determined	What actions can be performed on an object, what actions will this object require from other objects.	Implementing agent architecture and process modeling based on the Hopfield neural network. Application of tensor and tensor methodology to display linear multidimensional dynamic objects in a distributed space. The behavior of an object represented as a tensor in multidimensional space and the possibility of influencing this behavior are determined through special functions, which, when the coordinate system is changed, are transformed according to a linear law.
3. The relations between objects are determined	Relations between objects are established depending on the task.	Multi agent system. The basis of modeling distributed network computing is an associative structure that displays the processes and mechanisms of interaction of components at the corresponding nodes or nodes of the structure.
4. The specification of the interface of each object is determined	For the exchange of messages between objects, rules are determined for the adequacy of the object to the performed action.	A methodological approach based on the application of the principles of middleware, in which a set of objects (distributed elements) can be noted that determine its organization through processes in a distributed environment; this takes into account the phasing of information processes in a distributed network, from the request to its implementation in the form of a service.
5. Realization of objects	A list of object properties, messaging rules, and task diagrams is compiled. Based on the list of properties, the internal structure of the object is determined.	A hierarchical multi-level representation of a network with many information links between architectural and system components is defined as an information space corresponding to the space of an associative infocommunication network environment for transmitting and processing information, consisting of a hierarchically ordered set of metric spaces of a certain dimension.

Conclusion

The principles of the organization and functioning of the associative infocommunication network environment are applicable to models for the creation and analysis of information exchange processes in distributed network structures. In other words, the basis for modeling distributed network computing is an associative structure that displays the processes and mechanisms of interaction of components at the corresponding nodes or nodes of the structure.

The decomposition of the functional architecture of distributed systems is determined by the focus of the tasks of analysis and synthesis in the context of the effectiveness of the coordinated development of its functional architecture or the efficiency of the data exchange process, while it should be carried out in the plane of properties and grouping of subsets of functions of each level in the vertical plane in accordance with the selected subset of properties, each of which is formed by a certain subset of services of functional architecture; on the basis of this, the fundamental principles of the model of interaction of network elements as an abstract associative environment are considered. The elements of the structure of the associative environment, the possibilities of organizing a certain set of elements for the formation of the structure are determined, the sources that influence the change in the states of the elements for all reflection schemes describing the actual construction of the associative environment are determined.

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